

DEVELOPMENTAL TESTBED CENTER

Zoltan Toth, Bill Kuo, Louisa Nance, and Barbara Brown

Acknowledgements:

Ligia Bernardet, Brian Etherton, Tressa Fowler, Tara Jensen, Hui Shao, Ed Tollerud, Jamie Wolff, and Steve Koch

3rd NOAA Testbed Workshop, May 1, 2012

OUTLINE / SUMMARY

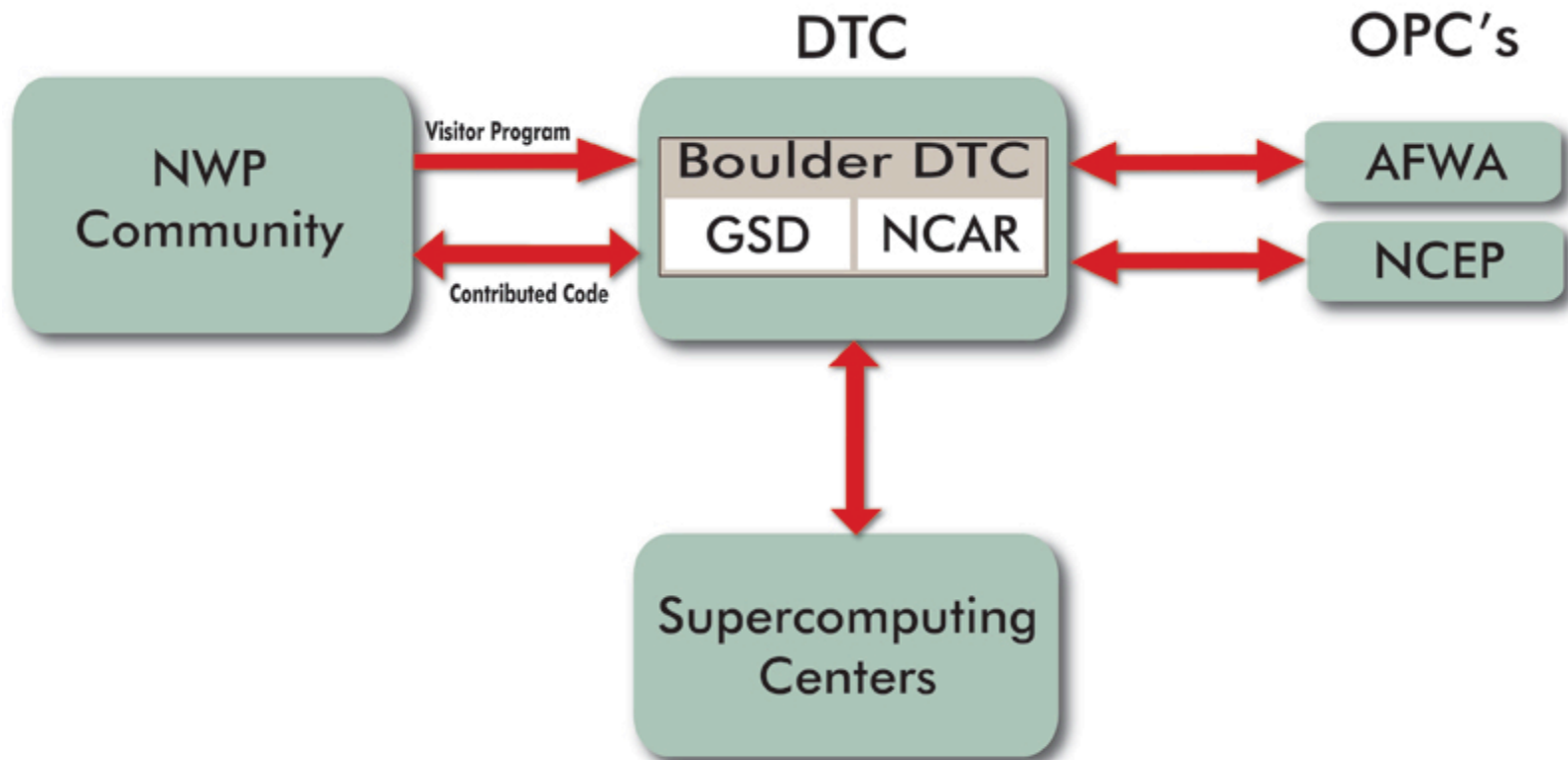
- What is DTC?
 - Facility to transition NWP community research into operations
- Main areas of work
 - Mesoscale Modeling, Data Assimilation, Ensembles, Hurricane Forecasting, Verification
- Links with other NOAA testbeds / programs
 - HMT, HWT, HFIP
- Outlook
 - Further integration with NOAA NWP activities
 - DTC's role in national NWP research, development, transition to operations

WHAT IS DTC?

- DTC is a distributed facility established in 2003 where
 - NWP community can test and evaluate new models & techniques
 - For use in research and operations
- Objective
 - To serve as a bridge between research and operations
 - To facilitate the activities of both halves of the NWP Community
 - In pursuit of their own objectives
- Benefits
 - Research community gets an environment functionally similar to operations to test and evaluate new NWP methods
 - Operational community benefits from DTC testing and evaluation of strengths and weaknesses of new NWP advances prior to consideration for operational implementation

MULTI-AGENCY EFFORT

The DTC Architecture



- DTC consists of ~45 staff (25 FTE)
 - NCAR/RAL/JNT
 - NOAA/ESRL/GSD
 - In strong partnership with
 - NOAA/NCEP/EMC, NCAR/NESL/MMM, and AFWA



MANAGEMENT

- Executive Committee
 - Principals from NOAA NWS & OAR, AFWA, NSF
- Management Board
 - Two representatives from each sponsoring organization
- Management Team
 - Director Bill Kuo
 - Assistant Director Louisa Nance
 - Deputy Director from NCAR/JNT Barbara Brown
 - Deputy Director from ESRL/GSD Zoltan Toth (Acting)
- Science Advisory Board
 - Cliff Mass, Chair

WHY ARE WE ENGAGED?

Excerpts from NOAA's Next Generation Strategic Plan

- **Holistic understanding of the Earth system through research**
 - NOAA's strategic progress and future operational capacity will depend upon a strong and *vibrant scientific enterprise that draws from NOAA research capabilities and the extended community of public, private, and academic researchers* with whom NOAA collaborates routinely
- **Integrated environmental modeling system**
 - The complexity of NOAA's modeling requirements and the challenges of transitioning research and development capabilities into operations will require *extensive coordination within NOAA and with other Federal Agencies for the optimized use of national investments, and external collaboration with the environmental modeling community in the academic (including academic consortia) and private sectors.* To this end, NOAA will develop collaborative strategies involving *internal and external partnerships and community-wide standards* to ensure interoperability
 - *Increased development and use of enterprise and community models*

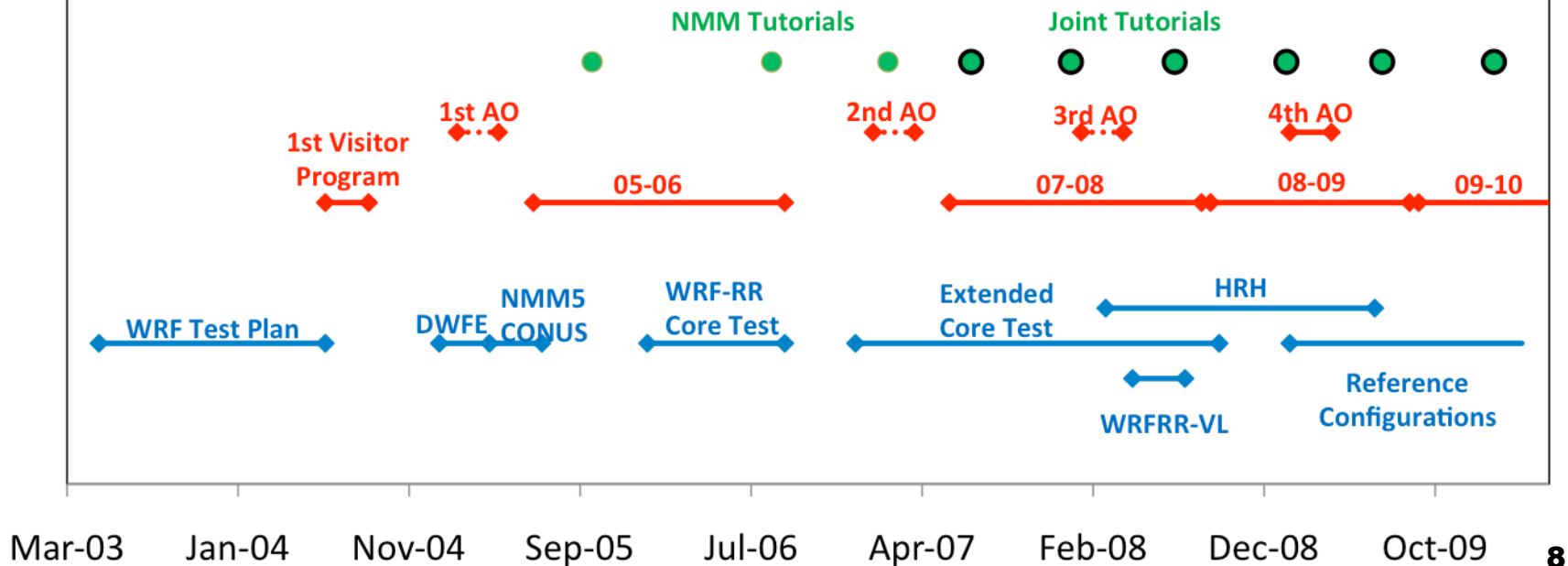
DTC HISTORY – WRF Activities

Operational Community

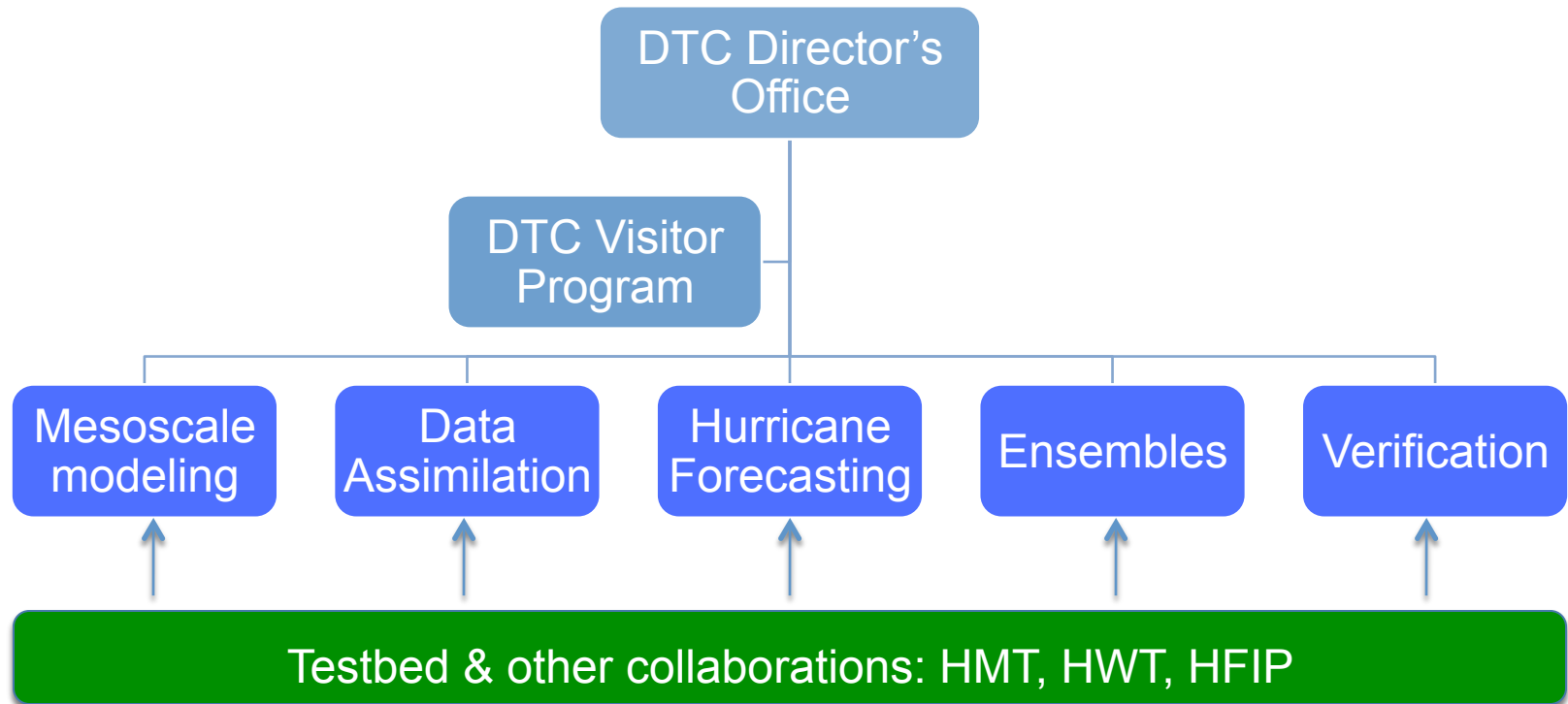
- Provide guidance for next generation Operational Configurations

Research Community

- Provide baselines for evaluating impacts of new techniques
- Aid in selecting configurations for research projects



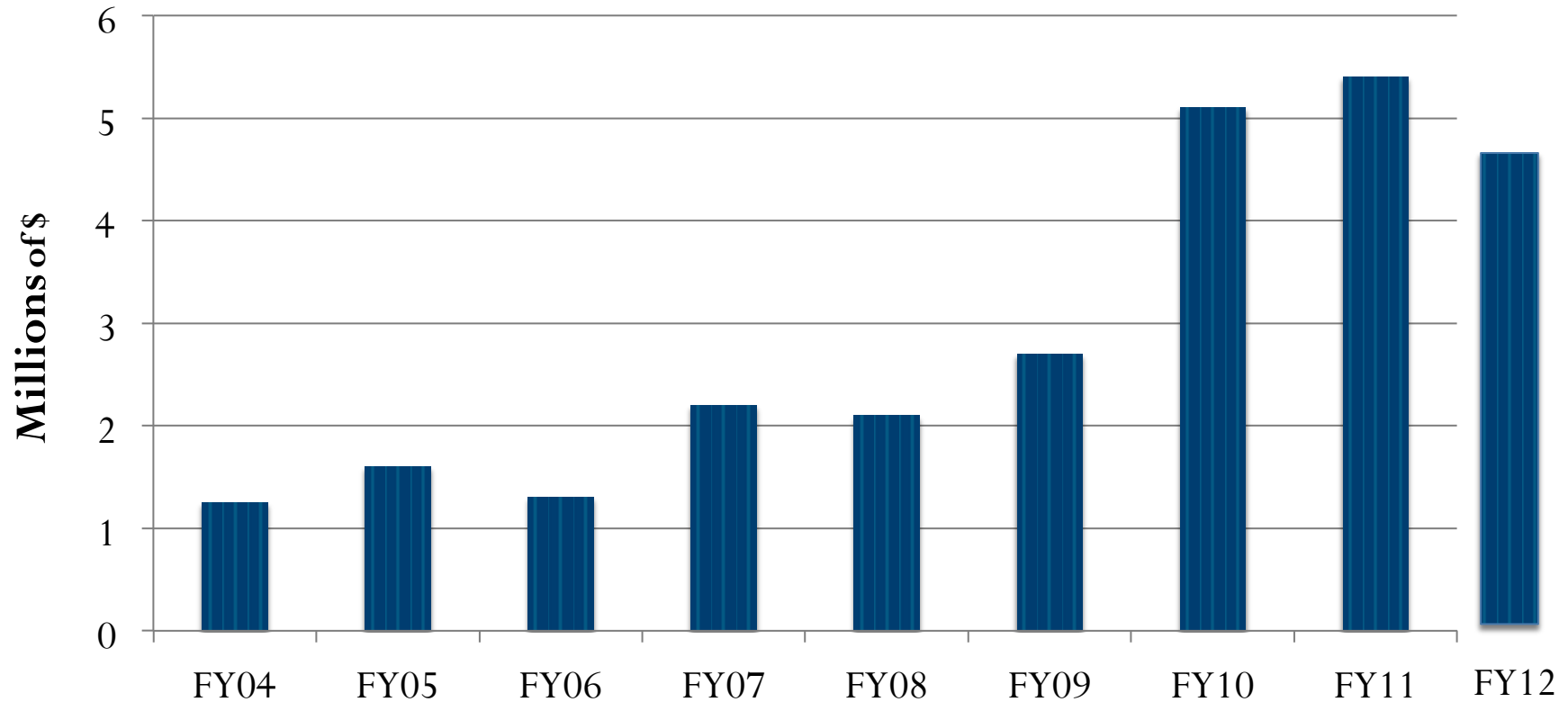
CURRENT DTC ACTIVITIES & ORGANIZATION



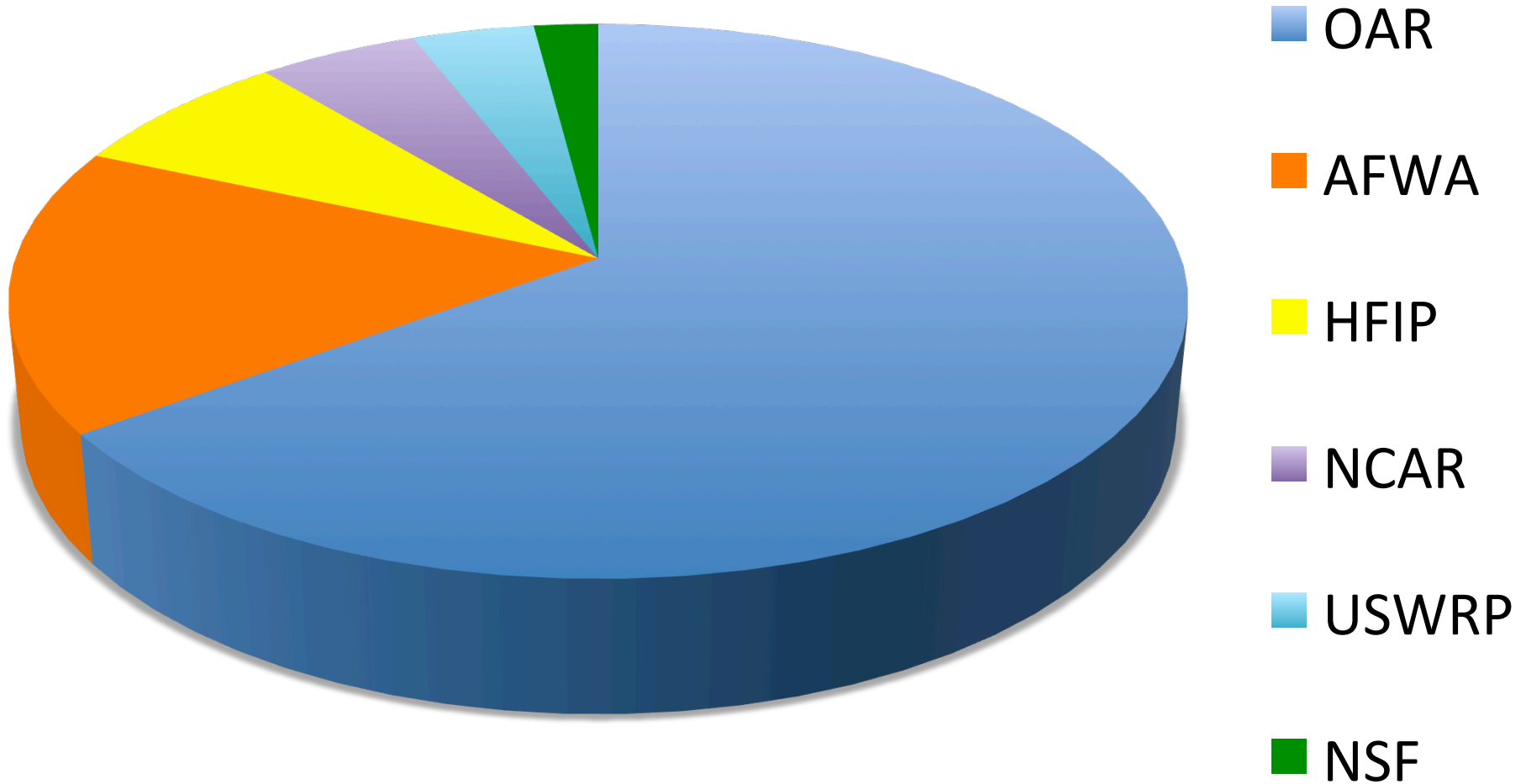
1. DTC activities focused on five key areas
2. HMT, HWT & HFIP are cross-cutting projects

DTC Budget

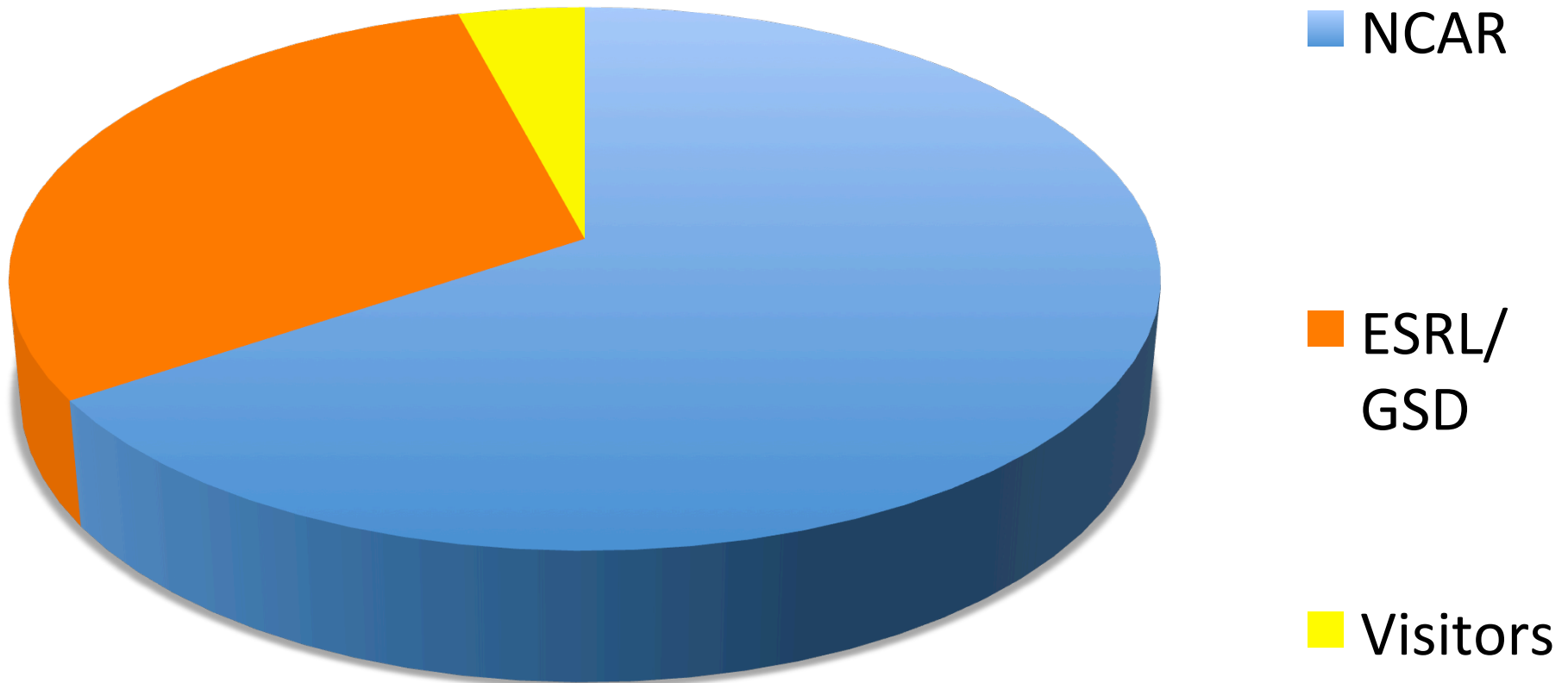
Funding Sources: NOAA, NCAR, AFWA, FAA, NSF



FY12 FUNDING SOURCES



FY12 EXPENDITURES



DTC ACTIVITIES

OPERATIONS TO RESEARCH (O2R)

- Maintain and support use of community / operational codes
 - Code repository
 - Tutorials / workshops
- Facilitate interactions between research & operations
 - Workshops
 - Visitor program
- Test & evaluation of promising community contributions
 - Transition successful methods to NCEP & AFWA
 - For further testing & possible operational implementation

RESEARCH TO OPERATIONS (R2O)

DTC Community Codes

Philosophy

- Free & shared resource
- Ongoing *distributed development* by both *research & operational communities* - maintained under version control
- *Periodic releases* made available to the community that include latest developments of new capabilities & techniques
- *Centralized support* (in collaboration w/ developers)
 - Software downloads
 - Documentation
 - Email helpdesk
 - Tutorials

Current Packages

- *WRF* (model, pre- & post-processors)
- WRF for Hurricanes (*HWRF*, coupled atmosphere-ocean model + TC post-processing tools)
- Gridpoint Statistical Interpolation (*GSI*) data assimilation system
- Model Evaluation Tools (*MET*)



DTC Community Support

Software	Code releases	Registered Users	Helpdesk inquiries (per month)	Onsite Tutorials	Online Tutorial
WRF & UPP	1 major (Apr) 1 minor (Aug)	~13,800	WRF ~400 NMM/WPP/UPP ~5-10%	Bi-annual ~70 students	Yes
HWRF & GFDL vortex tracker	Annual	HWRF: 340 Tracker: 105	~35	Annual ~30 students	Jan '12
GSI	Annual	482	~20	Annual ~30 students	Yes
MET	Bi-annual	1,582	~15	Bi-annual ~30 students	Yes

DTC-Sponsored Community Events (2011)

- Mesoscale Modeling
 - 12th WRF Users Workshop: 20-24 June 2011
 - NWP Workshop on Model Physics w/ an Emphasis on Short-Range Weather Prediction: 26-28 July 2011
- Hurricanes
 - Science day in conjunction w/ WRF for Hurricanes tutorial: 26 April 2011
- Data Assimilation
 - 1st GSI Workshop: 28 June 2011
 - BUFR/PrepBUFR Webcast Tutorial: 13 December 2011
- Ensembles
 - 5th NCEP Ensemble User Workshop: 10-12 May '11

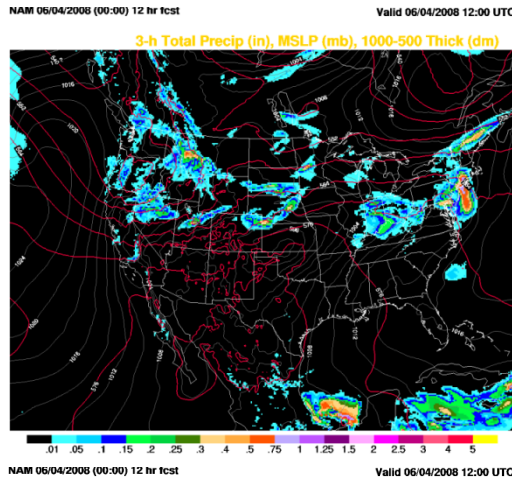
2012 DTC Visitor Projects

PI	Institution	Type	Project Title
Jonathan Vigh	NCAR	PI	Development of an HWRF Diagnostics Module to Evaluate Intensity & Structure Using Synthetic Flight Paths Through Tropical Cyclones
Adam Clark	U. of Oklahoma	PI	Development & Application of 3-Dimensional Object Algorithms to High Resolution Forecasts
Delia Arnold & Don Morton	Technical University of Catalonia / U. of Alaska –Fairbanks	PI	Moving The NEMS & NMM-B Into a Broader Community Resource Environment
Travis Wilson	UCLA	GS	Improvements to modeling persistent surface cold pools in WRF
Sai Ravela	MIT	PI	Deploying the MIT Field Alignment System & Test-bed (FAST) in DTC

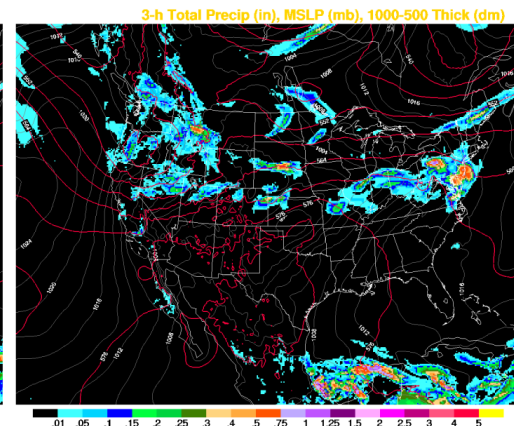
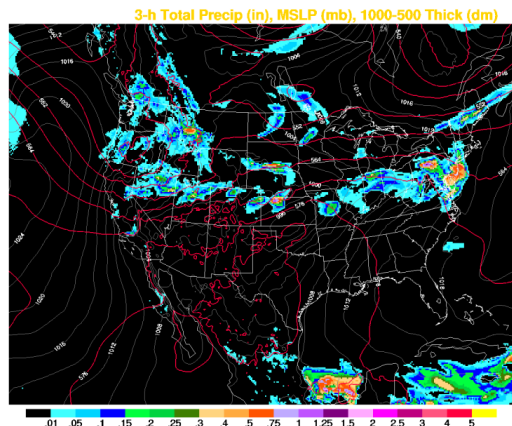
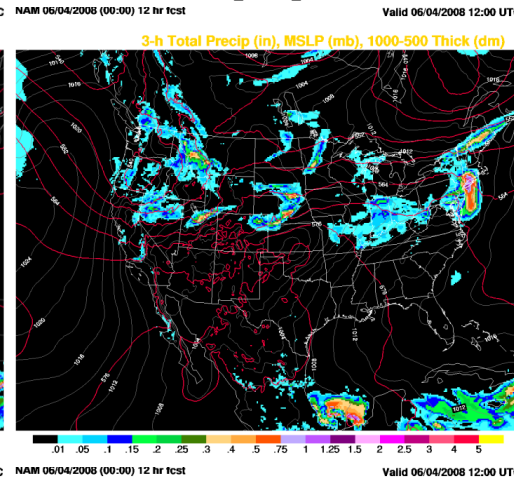
200k per year funding

MESOSCALE MODELING - Functionally similar operational environment (WRF-based)

No GSI



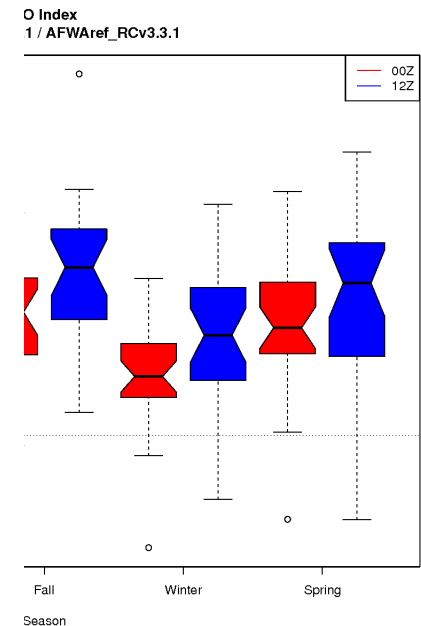
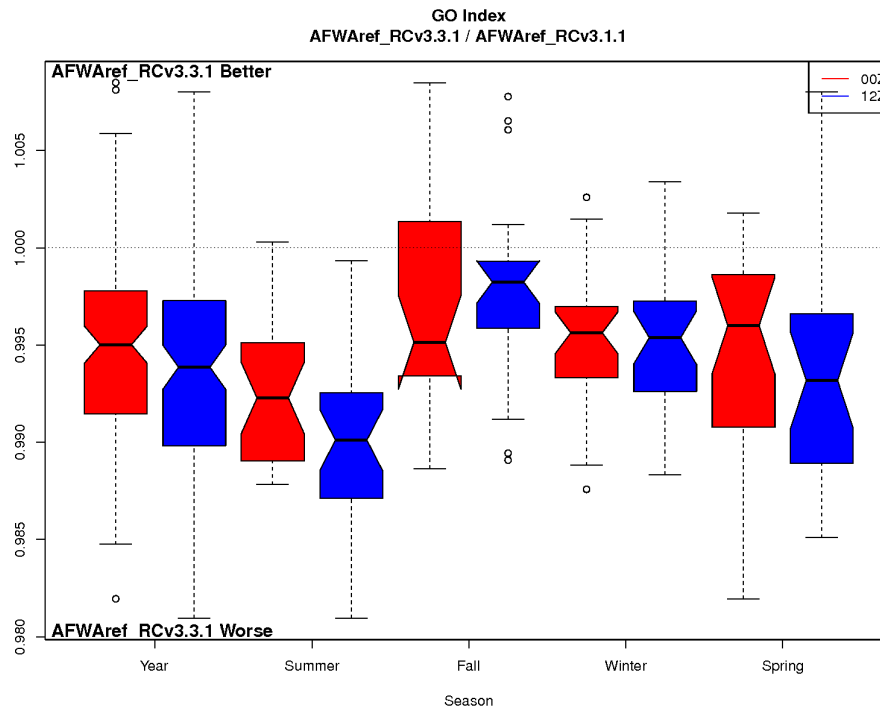
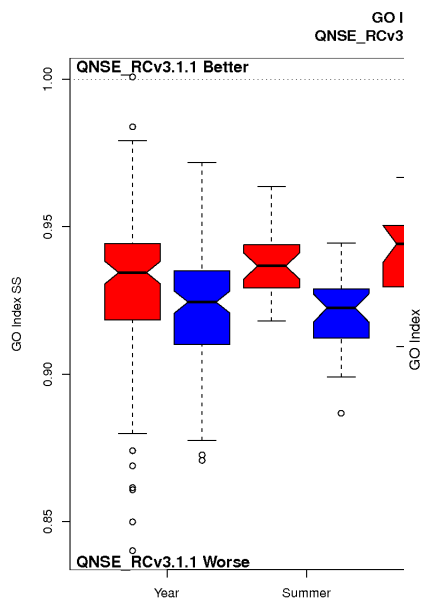
GDAS prepBufr



- Community GSI v3.0 integrated into end-to-end workflow
- Conducted observation impact study for two cases
 - Assimilated both prepBufr and satellite radiance datasets
 - Configured similarly to NAM RC
- Further tested system with one-month (noncycled) run
 - Assimilated NDAS prepBufr + GDAS radiance (AMSU-A, AMSU-B, MHS, HIRS3, HIRS4, AIRS)
 - Verification results compared to those from NAM RCT&E

WRF Innovation T&E

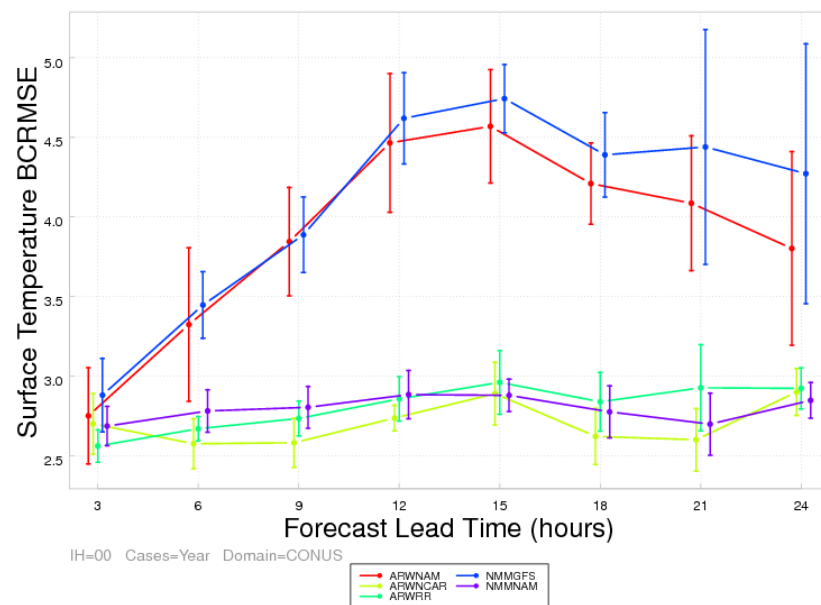
- Inter-comparison T&E allows for a quantitative assessment of forecast performance between
 - an operational baseline and community contributed scheme
 - two different versions of WRF using the same physics scheme



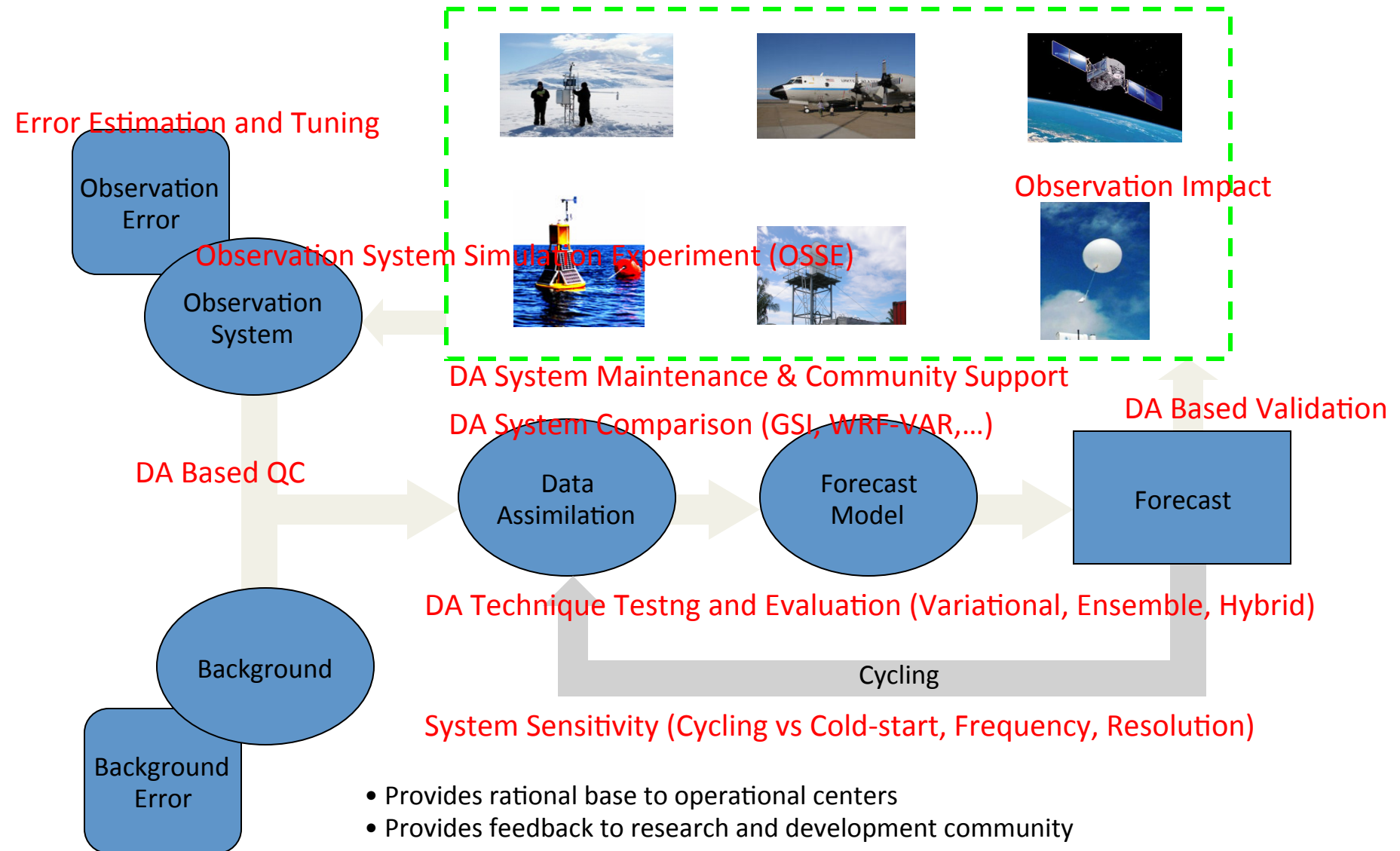
SREF Member Testing

- Request from EMC to assist in identifying appropriate configurations for the next implementation of the operational SREF
 - Worked with model developers as necessary to configure namelist settings
 - Ran initial sanity checks for each and adjusted as necessary
 - Ran more extensive testing for ~50 cases distributed throughout one full year
 - Provided temporally aggregated performance results to EMC

Physics Parameterization	ARW-NCAR	ARW-RR	ARW-NAM	NMM-NAM	NMM-GFS
Microphysics	WSM3	Thompson	Ferrier	Ferrier	Ferrier
Surface Layer	M-O Similarity	Eta Similarity	Eta Similarity	Eta Similarity	GFS
PBL	YSU	MYJ	MYJ	MYJ	GFS
Convection	Kain-Fritsch	Grell-3D	BMJ	BMJ	SAS
LSM	Noah	RUC	Noah	Noah	Noah
Radiation	RRTM/Dudhia	RRTM/Goddard	GFDL/GFDL	GFDL/GFDL	GFDL/GFDL



DATA ASSIMILATION - Test & Evaluation



Variational vs Hybrid Ens-Var

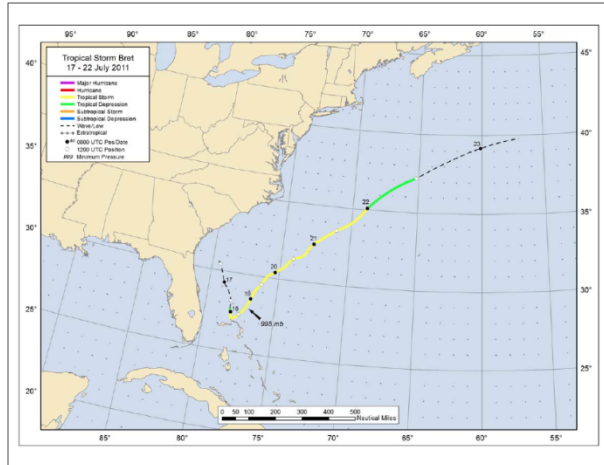
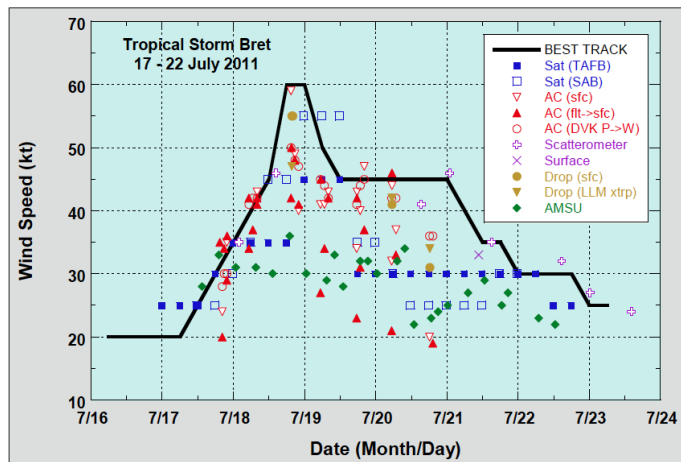
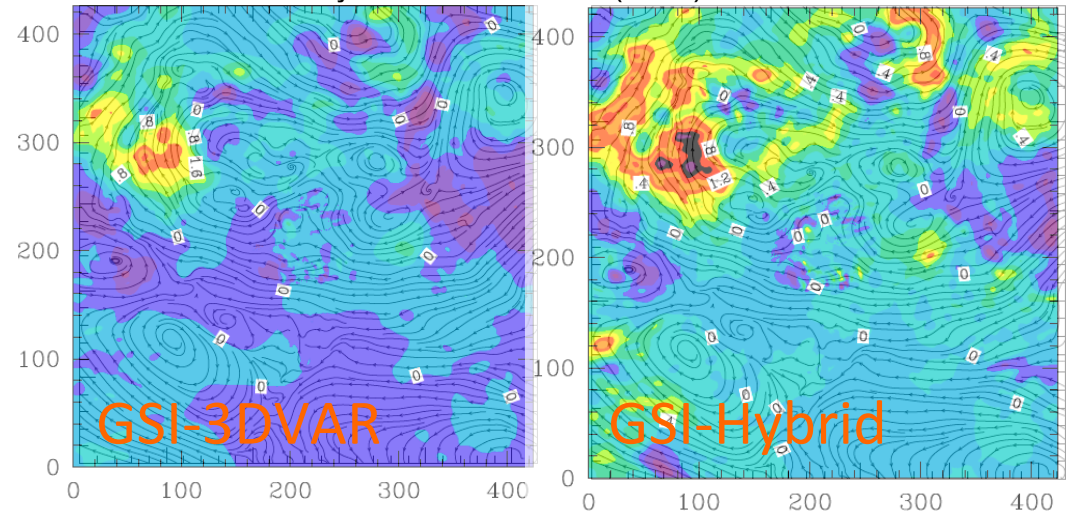


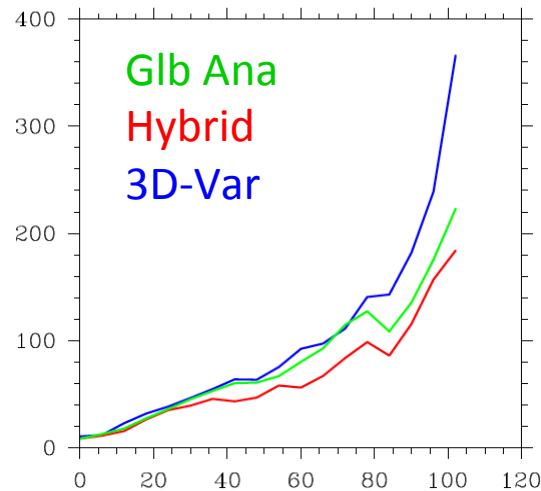
Figure 1. Best track positions for Tropical Storm Bret, 17-22 July 2011. Track during the post-tropical remnant low stage is based partly on analyses from the NOAA Ocean Prediction Center.



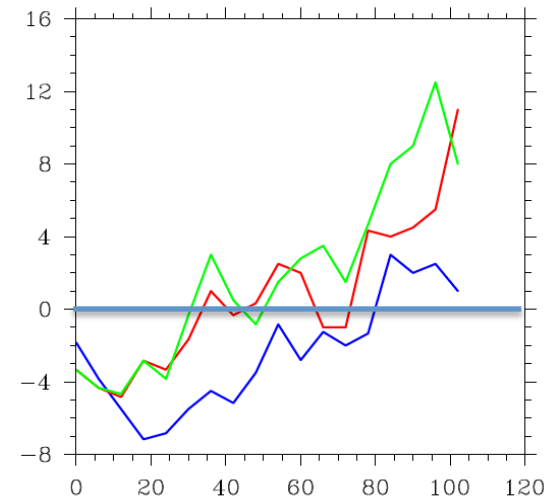
Analysis increment of T (color) and Streamline



Track Error



Intensity Error



HURRICANE FORECASTING

Goal: Tech Transfer to Hurricane NWP

Current focus on Hurricane WRF model (Weather Research and Forecasting)

1. Code Management

- Create a framework for NCEP and the research community to collaborate

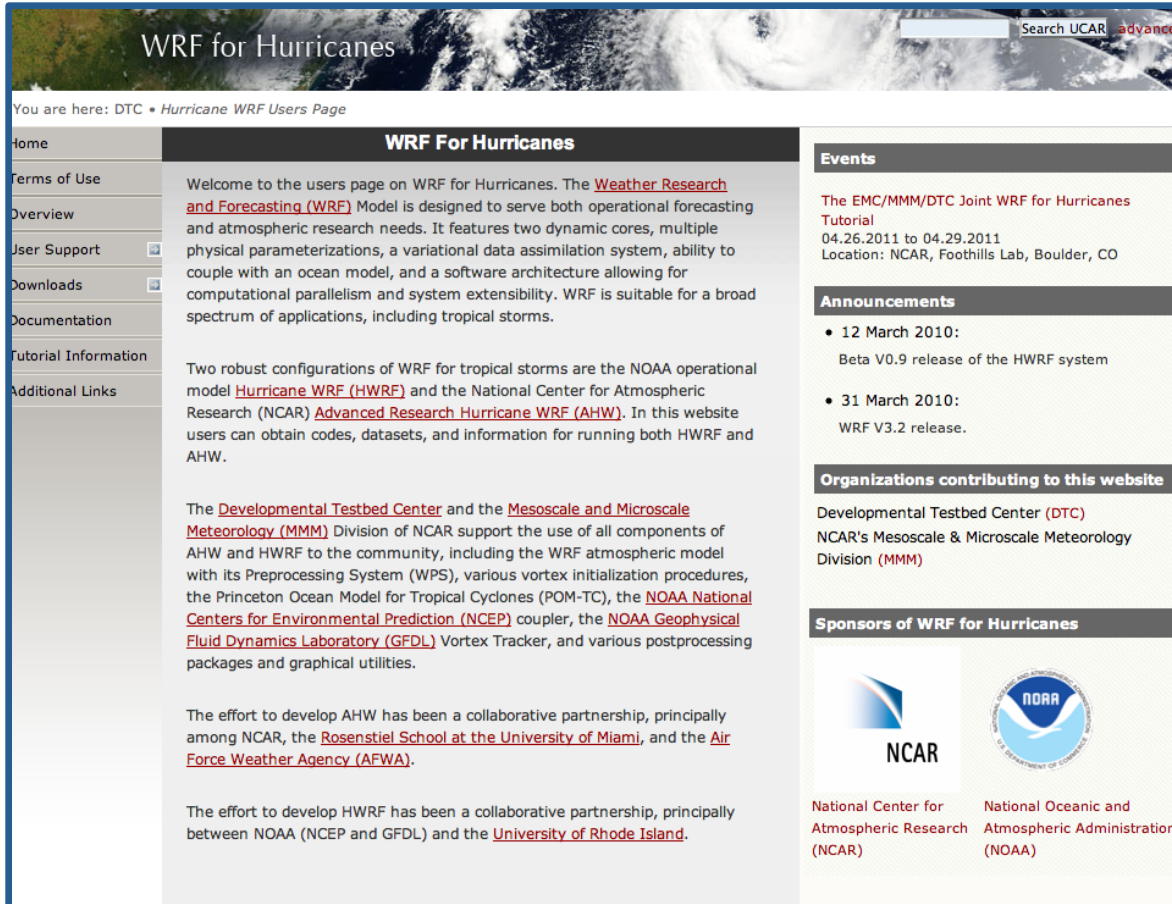
2. User Support

- Support the community in using an operational hurricane model

3. Testing and Evaluation

- Ascertain integrity of the code
- Conduct diagnostics on operational configuration
- Evaluate new developments for potential operational implementation

WRF for Hurricanes User Support



WRF for Hurricanes

You are here: DTC • Hurricane WRF Users Page

WRF For Hurricanes

Welcome to the users page on WRF for Hurricanes. The [Weather Research and Forecasting \(WRF\)](#) Model is designed to serve both operational forecasting and atmospheric research needs. It features two dynamic cores, multiple physical parameterizations, a variational data assimilation system, ability to couple with an ocean model, and a software architecture allowing for computational parallelism and system extensibility. WRF is suitable for a broad spectrum of applications, including tropical storms.

Two robust configurations of WRF for tropical storms are the NOAA operational model [Hurricane WRF \(HWRF\)](#) and the National Center for Atmospheric Research (NCAR) [Advanced Research Hurricane WRF \(AHW\)](#). In this website users can obtain codes, datasets, and information for running both HWRF and AHW.

The [Developmental Testbed Center](#) and the [Mesoscale and Microscale Meteorology \(MMM\)](#) Division of NCAR support the use of all components of AHW and HWRF to the community, including the WRF atmospheric model with its Preprocessing System (WPS), various vortex initialization procedures, the Princeton Ocean Model for Tropical Cyclones (POM-TC), the [NOAA National Centers for Environmental Prediction \(NCEP\)](#) coupler, the [NOAA Geophysical Fluid Dynamics Laboratory \(GFDL\)](#) Vortex Tracker, and various postprocessing packages and graphical utilities.

The effort to develop AHW has been a collaborative partnership, principally among NCAR, the [Rosenstiel School at the University of Miami](#), and the [Air Force Weather Agency \(AFWA\)](#).

The effort to develop HWRF has been a collaborative partnership, principally between NOAA (NCEP and GFDL) and the [University of Rhode Island](#).

Events

The EMC/MMM/DTC Joint WRF for Hurricanes Tutorial
04.26.2011 to 04.29.2011
Location: NCAR, Foothills Lab, Boulder, CO

Announcements

- 12 March 2010:
Beta V0.9 release of the HWRF system
- 31 March 2010:
WRF V3.2 release.

Organizations contributing to this website

Developmental Testbed Center (DTC)
NCAR's Mesoscale & Microscale Meteorology Division (MMM)

Sponsors of WRF for Hurricanes

NCAR
National Center for Atmospheric Research (NCAR)

NOAA
National Oceanic and Atmospheric Administration (NOAA)

Code downloads,
datasets,
documentation,
helpdesk

370 registered users

Yearly releases
corresponding to
operational model of
the year

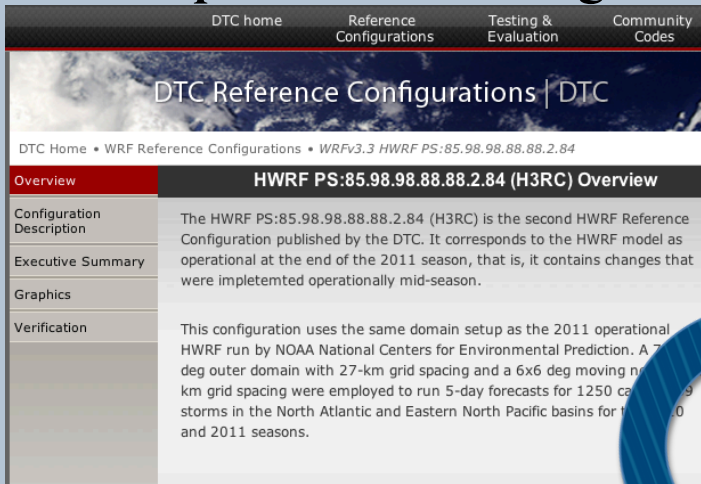
Stable, tested code

Benchmarks available

DTC provides developers with access to the centralized research/operations repository. Allows obtaining latest experimental code and adding contributions = **clear path to operations**

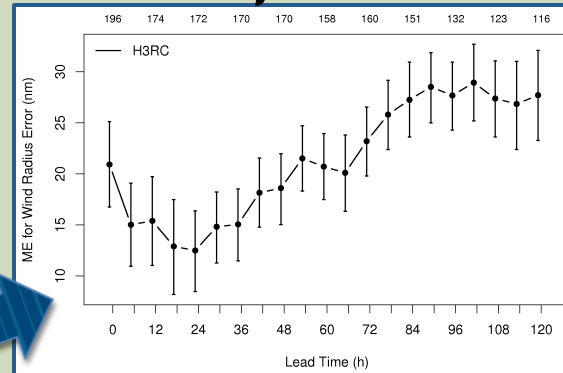
HWRF Testing, Evaluation, Diagnostics

Comprehensive testing



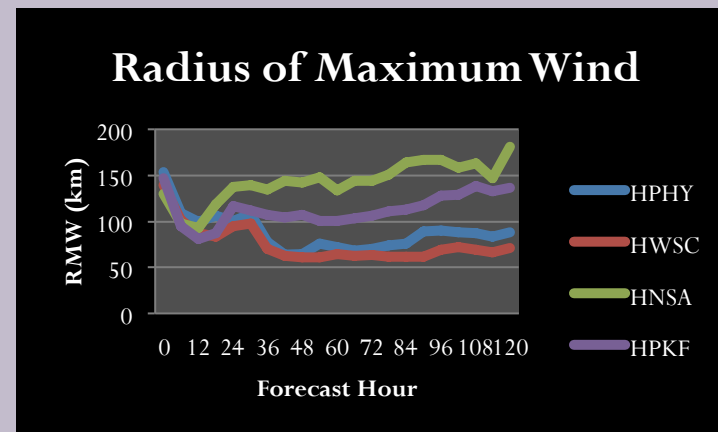
- Results available at dtcenter.org
- Functionally-equivalent testing suite
- Multi-season tests, thousands of runs
- Benchmarks of community code
 - Inform future development
 - Control to test improvements

Summary Statistics



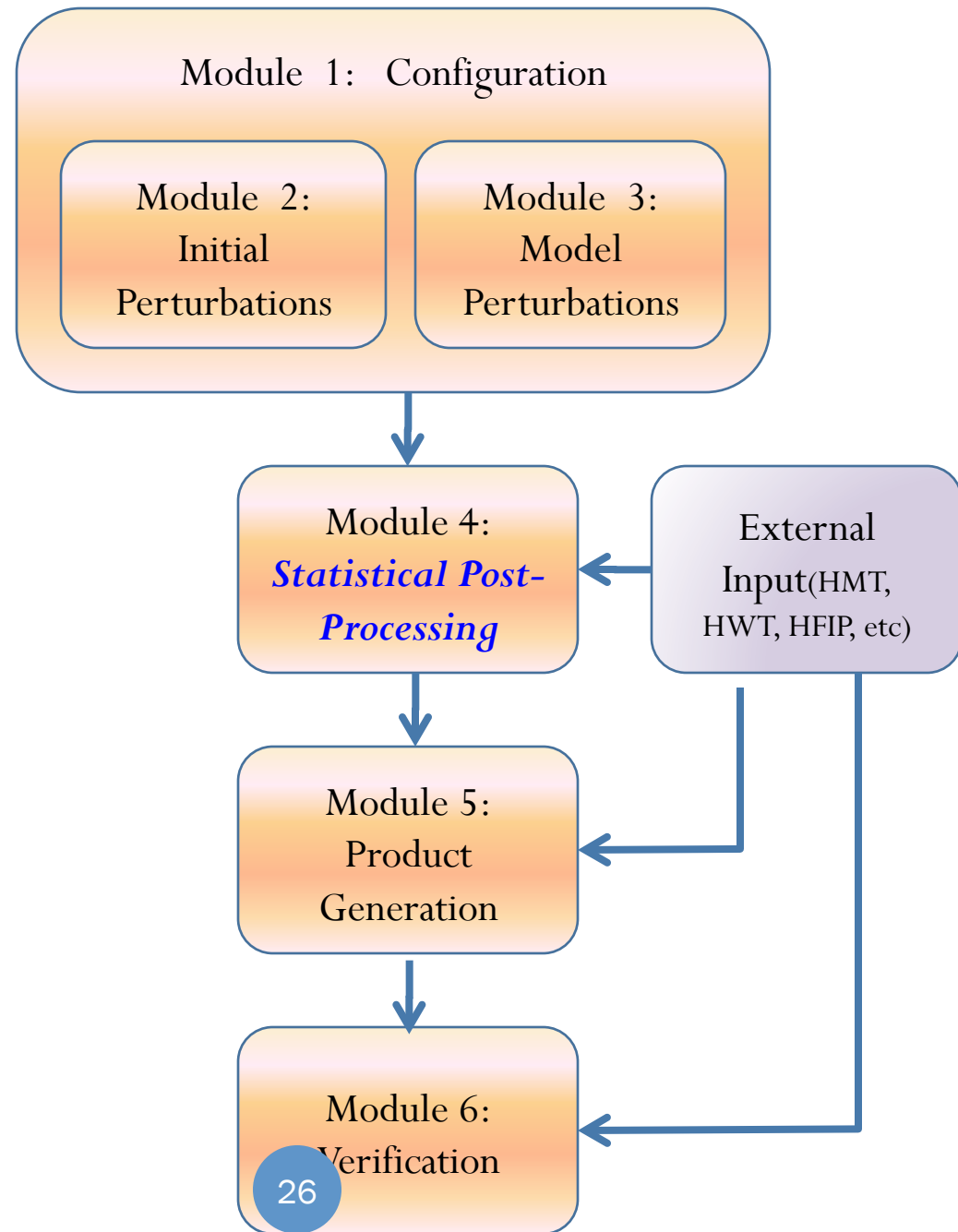
Average wind radii error for 64 kt threshold (NE):
Inner core too large; contracts during first day

Case Studies / Small tests



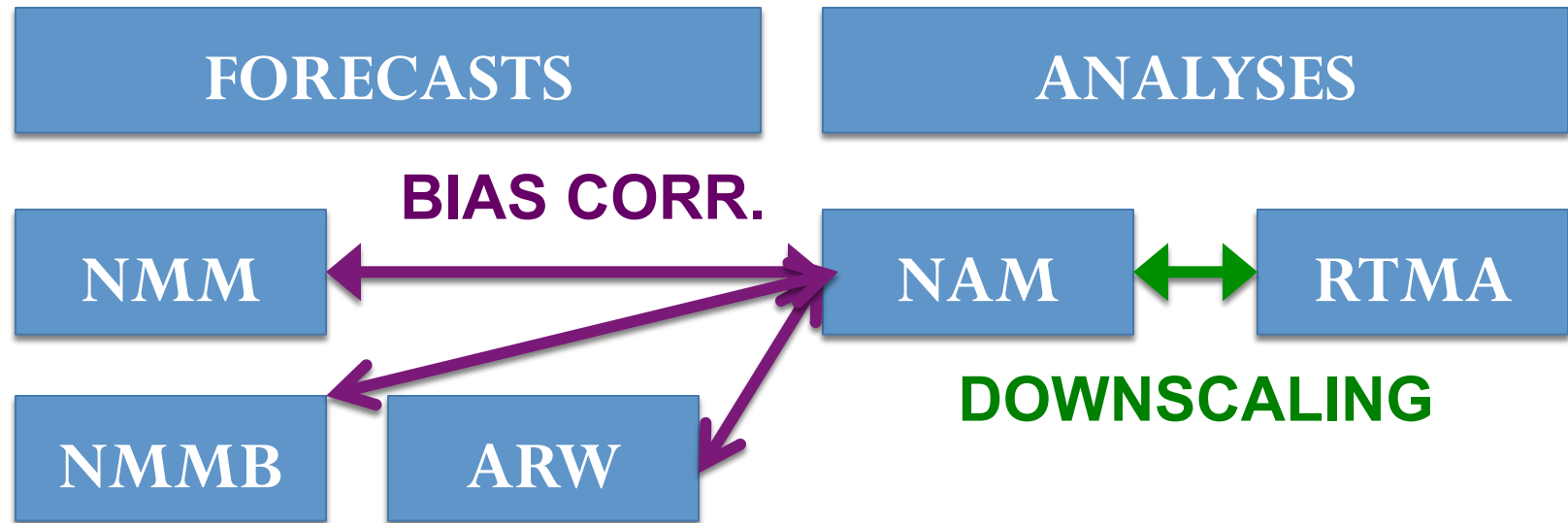
4 cumulus schemes:
Inner core size sensitive to cumulus

ENSEMBLE MODULES



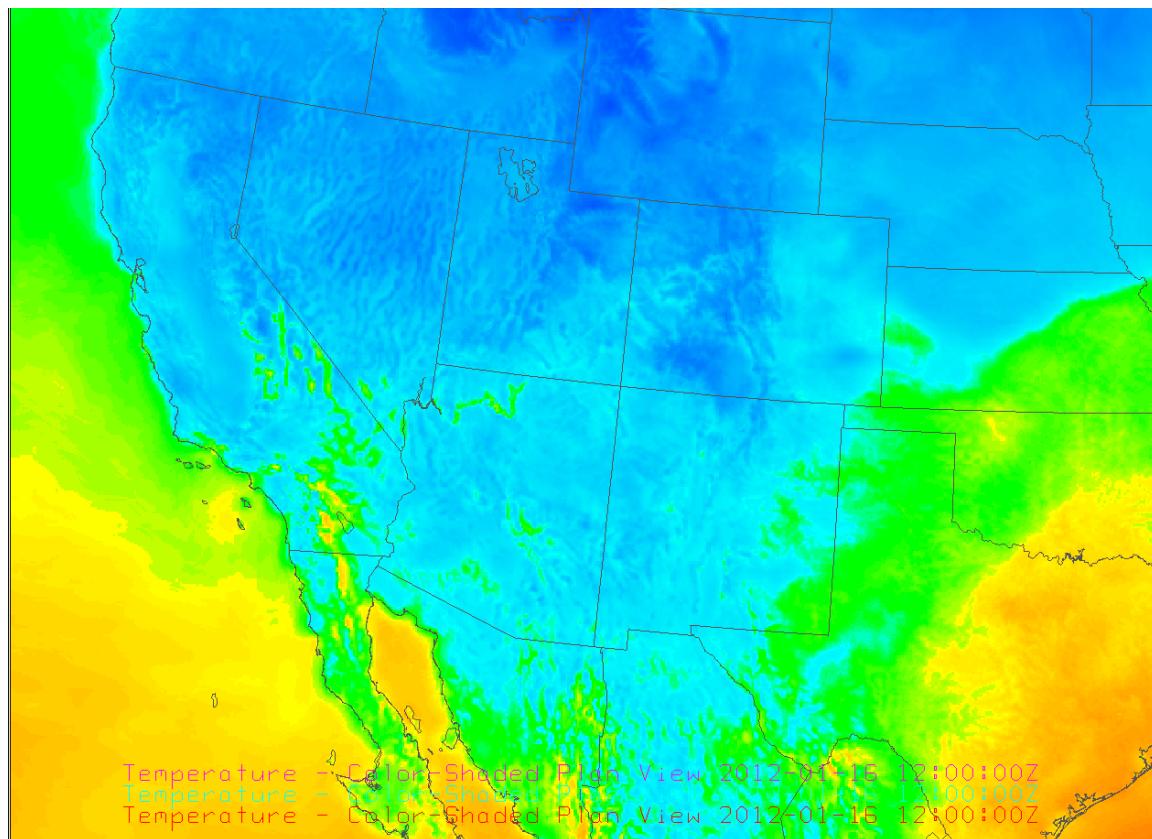
ENSEMBLES - DTC implementation of NAEFS

Downscaling for NCEP SREF



- Bias Correction is accomplished by taking the mean forecast of each model core (ARW, NMM, etc.) sub-ensemble of the NCEP SREF and comparing it to the NAM analysis valid at the same time.
- Downscale by comparing the RTMA analysis (GRID 259, like GRID 197, 1073x689, 5.079km) with the NAM analysis valid at the same time (10m wind, 2m temperature and humidity).

Implementation of downscaling at EMC



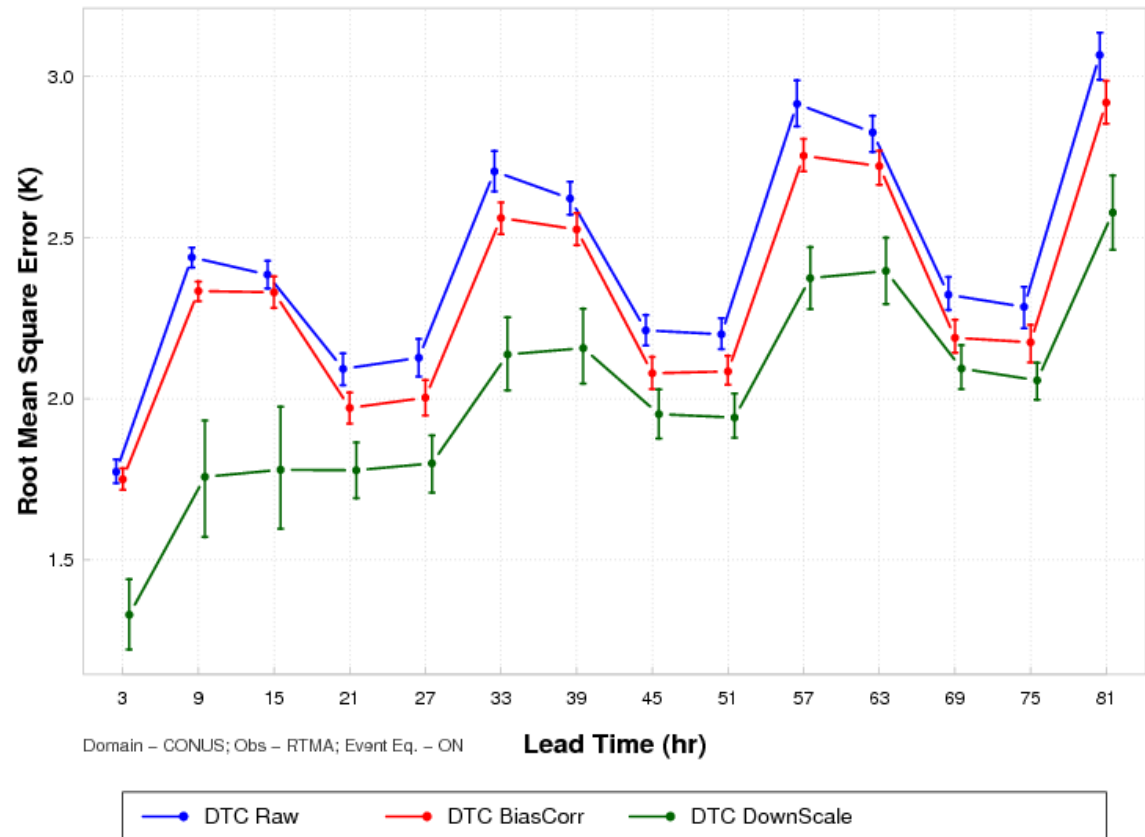
Raw SREFx, Bias corrected SREFx, and downscaled SREFx forecasts (initialized 2100UTC 12 Jan 2012, valid 1200UTC 16 Jan 2012, 87-hour forecasts)

- Downscaling code used in NAEFS ported to DTC in early summer
- Testing/evaluation of the application of this code to the existing NCEP SREF output showed forecast improvement
- DTC code sent to EMC for application to the new NCEP SREF, implemented in approximately 2 days, with downscaled forecasts being produced since December 7th

RMS ERRORS

- As implemented at DTC (using archived NCEP SREF ensemble output), downscaling decreased root mean squared error (compared to RTMA) at all lead times.

**DTC Tests of SREF BiasCorrection and NAEFS Downscaling
2m Temp RMSE – Aggregation for 10 Jun – 10 Jul 2011**



VERIFICATION

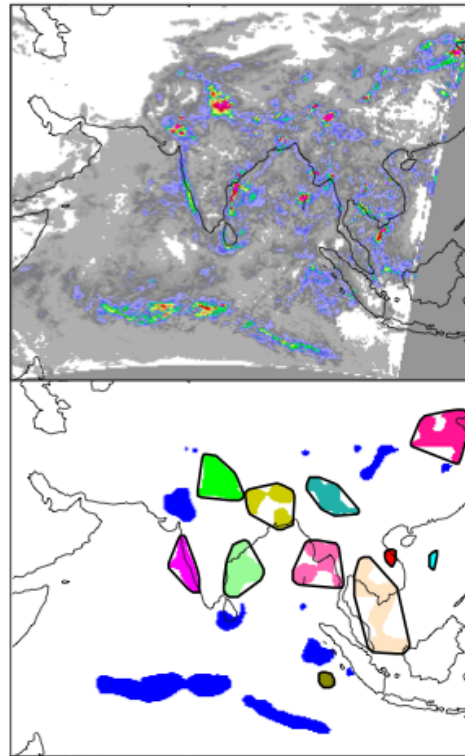


Support and Tools for verification.

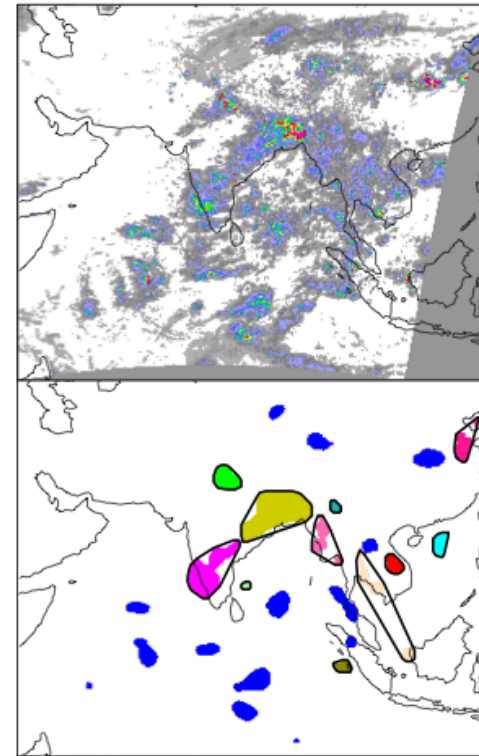
- Advice and consulting on all DTC verification activities.
- MET (Model Evaluation Tools).
- **New** Hurricane Verification Tools coming in June.

New Capability Example: MODE Vx
with TRMM Satellite Observations

Forecast



Observation



Latest MET Enhancements



- Confidence Intervals for MODE attributes in support of Testing & Evaluation.
- MADIS data ingest.
- Investigate ensemble spread vs skill.
- Create vertical MODE objects from CloudSat.
- User contributed TRMM2nc converter posted to MET web page.

HMT – DTC Collaboration

QPF Verification during 3 Winter Seasons

Research Objective: Design Verification techniques for QPF During Atmospheric Rivers (ARs) and Extreme Precipitation in the CA Mountains

Research Objectives Require Addressing These issues:

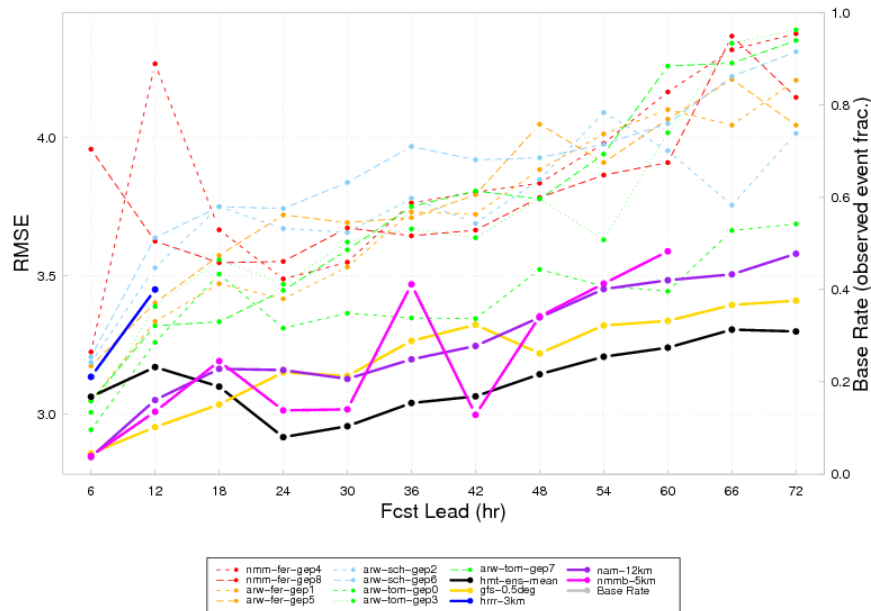
- 1) Problem of causes (ARs) and effects (extreme precipitation in CA)
- 2) Impacts Due to:
 - ✓ Models of different domains and resolutions
 - ✓ Precipitation regimes: Marine and orographic
 - ✓ Severe penalties for matched-pair verification
 - ✓ Sparse and problematic verification data
- 3) Ensemble forecasts and MET/MODE: shape ‘averaging’
- 4) Model comparison and model development (eg., microphysics)

Further details: Two related HMT papers in later sessions

Standard Scores for Inter-model comparisons

- Results for December 2010
- Black, yellow, magenta, purple, blue: HMT ensemble mean, GFS, NAM, NMMB, HRRR
- Dashed – HMT ensemble members

30 Day AGGREGATION for APCP_06 >0.000" RMSE
VALID TIME ENDING: 20101231 Region: LAND_d01 Obs: StageIV

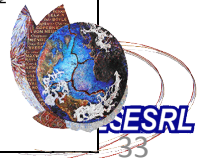
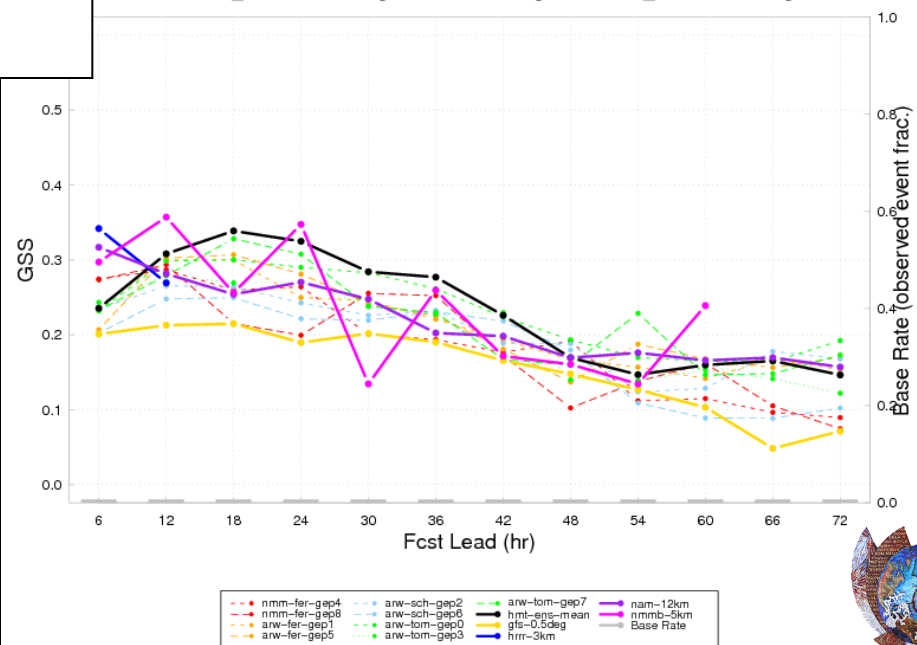


RMSE, inches

Note advantage to higher resolutions

Gilbert Skill Score,
1.0 inch threshold

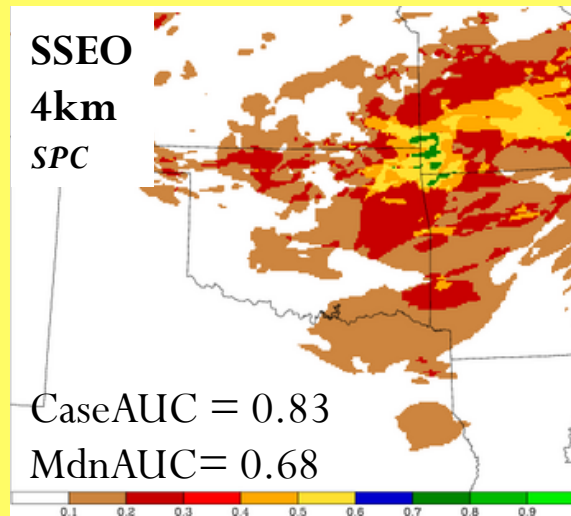
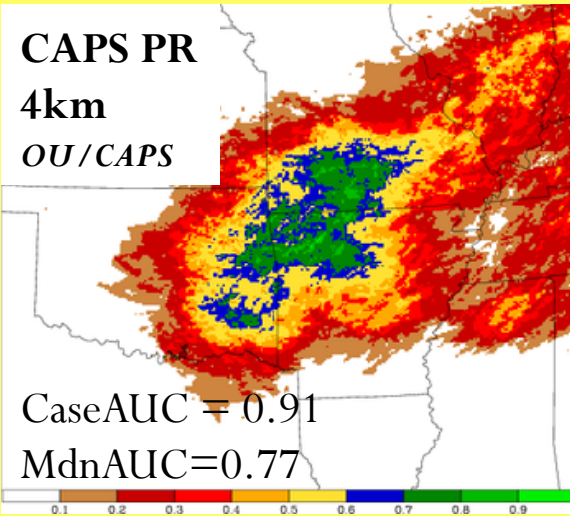
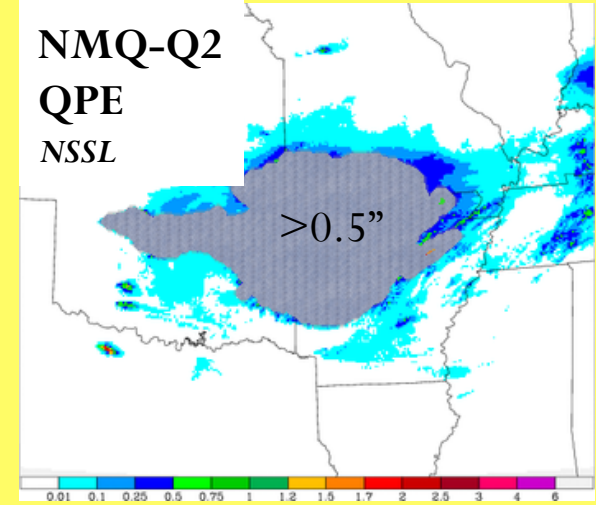
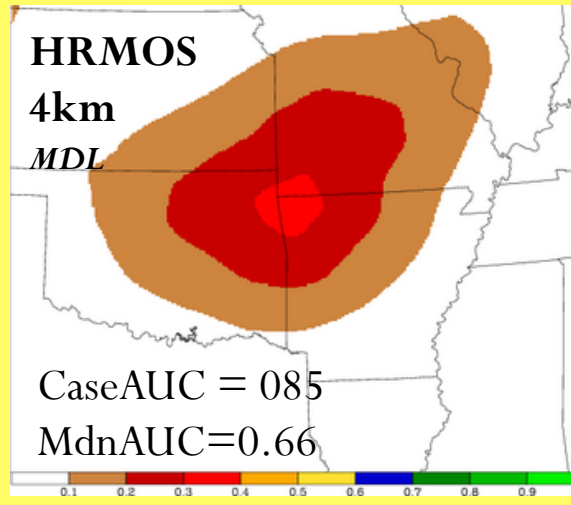
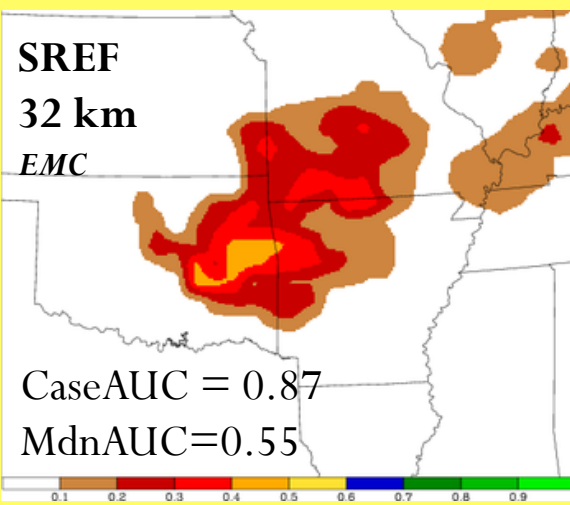
30 Day AGGREGATE for APCP_06 >=1.000" GSS
OVER FCST_LEAD - Ending 20101231 - Region: LAND_d01 Obs: StageIV



HWT – DTC COLLABORATION

- Started collaboration in 2008
 - Introduced objective evaluation into the testbed environment; including new verification methods based on
 - Objects
 - Neighborhood
 - Wavelet decomposition
 - Provided automated evaluation of many contributed models in 2011:
 - 48 member CAPS multi-model ensemble
 - 7 member time-lagged ensemble of current operational 4km models
 - Operational baselines: SREF, NAM, NMM-B parallel, HRRR
 - Research baselines: MMM, LAPS
 - Provided tutorials with on-site personnel for many of the weeks during the 2009-2011 seasons
- Use of DTC objective evaluation from 2011 highlighted in later talk:
Wed @1:20 Operational Impact of the QPF Component of the 2011 Spring Experiment, Faye Barthold

Hazardous Weather Testbed (HWT) 2011 SE Probability Fields



SREF – Current Operational Ensemble from EMC
HRMOS - HiRes Model Output Statistics from MDL
SSEO – 7 HiRes models available to HPC and SPC
CAPS – 4km Multi-Phys Ensemble available for HWT

Valid: 20110524 06 UTC

Threshold: 6hr Precip ≥ 0.5 "

Area Under the Curve (AUC) – ability to discriminate btw event / non-event – 1 optimal – 0.5 no-skill



Courtesy of Tara Jensen and OU/CAPS, SPC, NSSL, EMC

35 DL

DTC-RELATED TALKS / POSTER ON WEDNESDAY

- **1:20-1:40** Operational Impact of the QPF Component of the 2011 Spring Experiment (*Faye E. Barthold, I.M Systems Group, Inc., & NWS/HPC*)
- **2:20-3:20** Experimental Regional Ensemble System (ExRES) – Plans for 2012 and Beyond (*Brian Etherton, OAR/ESRL/GSD*) - Poster
- **3:40-4:00** Spatial Verification of Atmospheric Rivers (*Wallace Clark, Science and Technology Corp. & OAR/ESRL/PSD*)
- **4:20-4:40** Verification and Diagnoses of Ensemble QPF Forecasts during Extreme Events in California during the HMT Winter Exercises (*Tara Jensen, NCAR/RAL*)

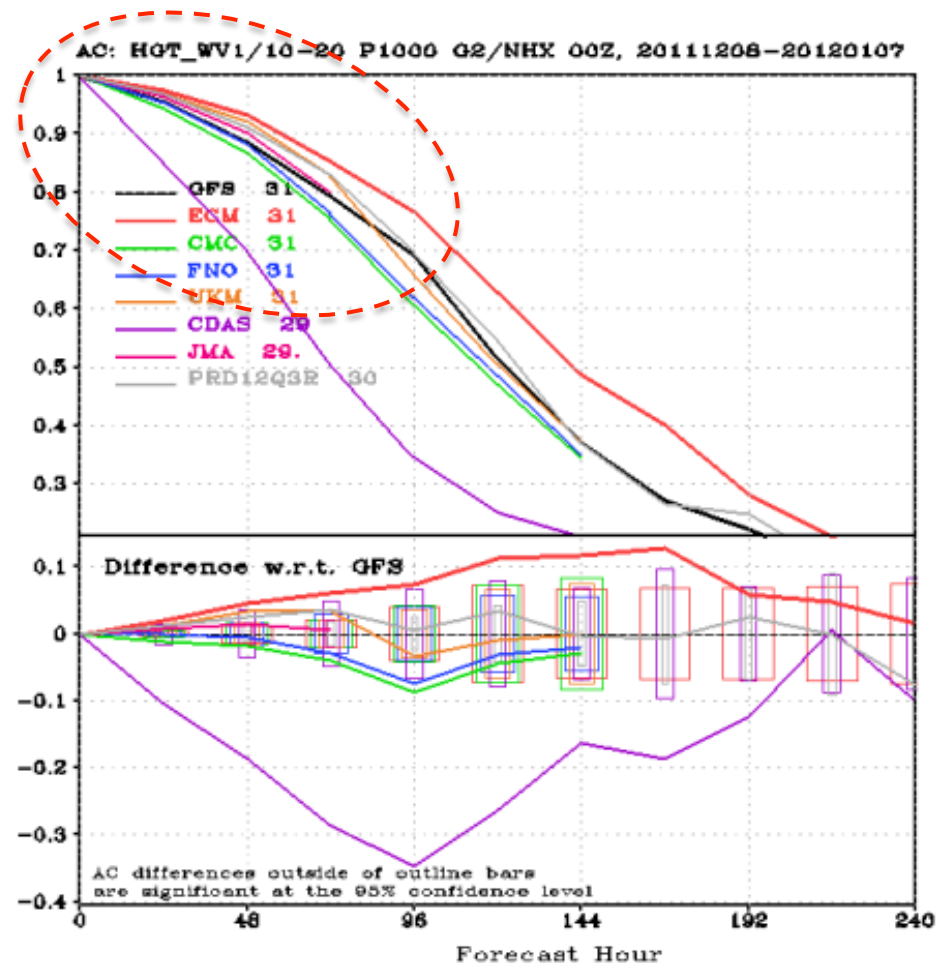
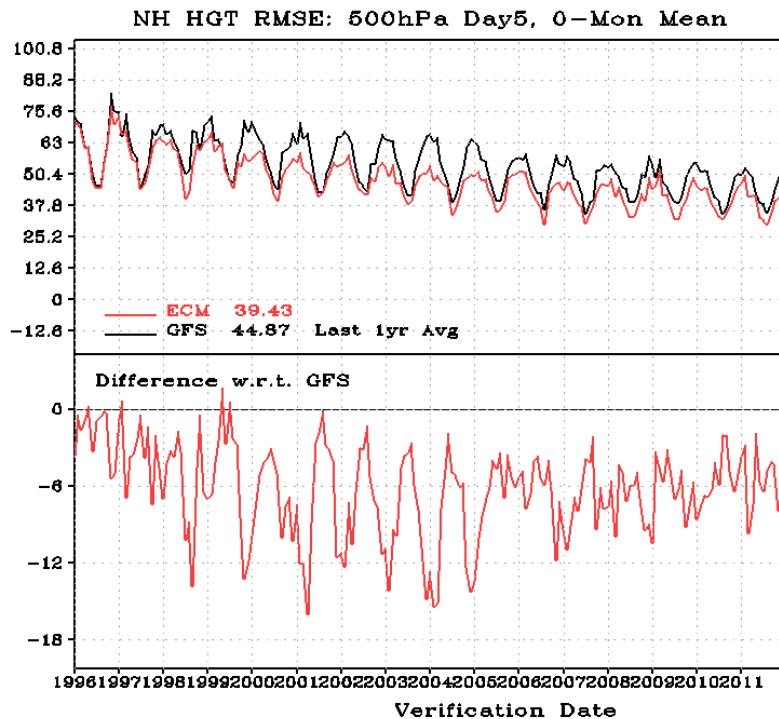
DTC'S ROLE IN NOAA

- How to define role of DTC in context of other NOAA testbeds and programs?
- HMT, HWT, ATC, JHT, etc
 - Focus on various application areas
- DTC
 - National testbed for NWP
 - Integrate NWP innovations from other NOAA testbeds / programs into NOAA operations
- How to improve efficiency?
 - Involve DTC in NWP-related activities at other testbeds?
 - Coordinated Announcement of Opportunities
 - Testbeds, DTC, NSF?

EXPECTATIONS OF / CHALLENGES FOR DTC

- National “scorekeeper” for WRF
- Transition NWP community research into operations
 - Who funds community NWP research?
 - Who sets long term plans for NOAA NWP operations?
- Propel US NWP into international leadership position
 - WRF scores do not make it into international comparisons
 - *Disconnect between expectations and current activities of DTC*
- What is the future of NWP?
 - DTC evolved from WRF modeling to encompass
 - Data assimilation, ensembles, hurricane forecasting
- What is next for DTC?
 - Mesoscale modeling 10 yrs ago meant limited area domain
 - Today, mesoscale research shifting to global domain?
 - MPAS, NIM, Multiscale models with superparameterization, etc.
 - Simplified NWP suite with adaptive resolution global models?

NH 500 Height skill comparison



BEYOND AOP12 & AOP13

- Need vision, mission, & long term plan for DTC
 - In close collaboration with NWS
- What the community expect from DTC?
 - Help US regain leadership in NWP
- What our sponsors expect from DTC?
 - DTC Executive Committee endorsed 20-60-20% effort on
 - Short (<1 year) – medium (2-3 yrs) – long (3+ yrs) term efforts
- How can DTC help US operational NWP regain its leadership?
 - Contribute to development, testing, and transition of
 - *Next generation DA, modeling, and ensemble systems*
- Current focus on limited area modeling
 - Cost effective to expand effort to global domain?

LOOKING AHEAD

- MISSION

- Transition cutting edge community research into the nations' operational Numerical Weather Prediction centers

- VISION

- Become an internationally recognized center to facilitate community development in Numerical Weather Prediction

LONG-TERM PLAN

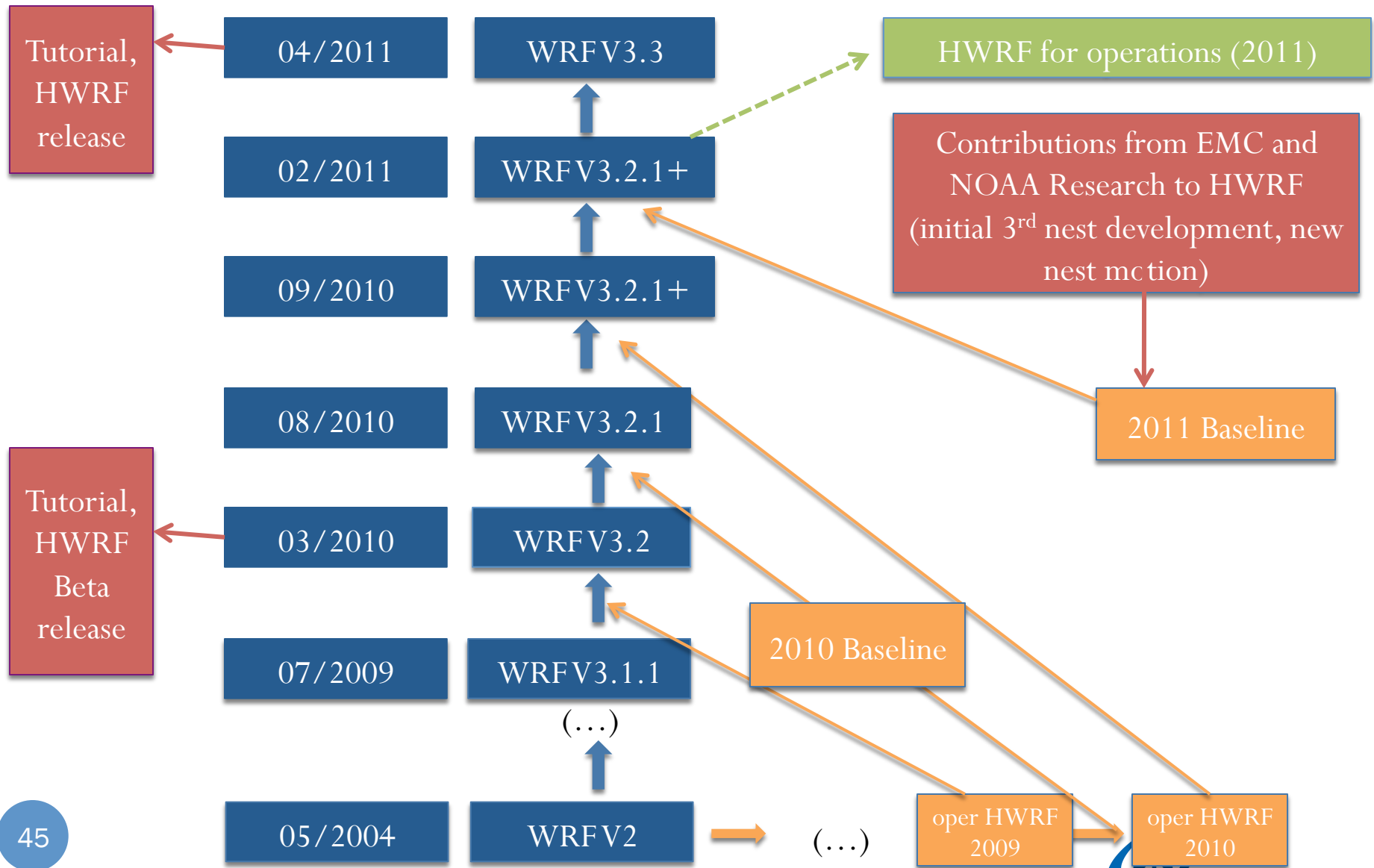
- Catching up is not going to happen next year
 - Not in next 3 yrs perhaps
 - Aim at next generation systems (3-5+ years)
- Organize & work w. community to facilitate development of
 - *Next generation DA, modeling, & ensemble systems*
- Develop long-term plan in strong coordination with NWS
 - Hold Community / DTC Strategic Planning Workshop
 - Organize Community Global Modeling summit?
 - Next generation DA Developers meeting?
 - Ensemble Developers Workshop
 - June 27-29, 2012, Boulder

OUTLINE / SUMMARY

- What is DTC?
 - Facility to transition NWP community research into operations
- Main areas of work
 - Mesoscale Modeling, Data Assimilation, Ensembles, Hurricane Forecasting, Verification
- Links with other NOAA testbeds / programs
 - HMT, HWT, HFIP
- Outlook
 - Further integration with NOAA NWP activities
 - DTC's role in national NWP research, development, transition to operations

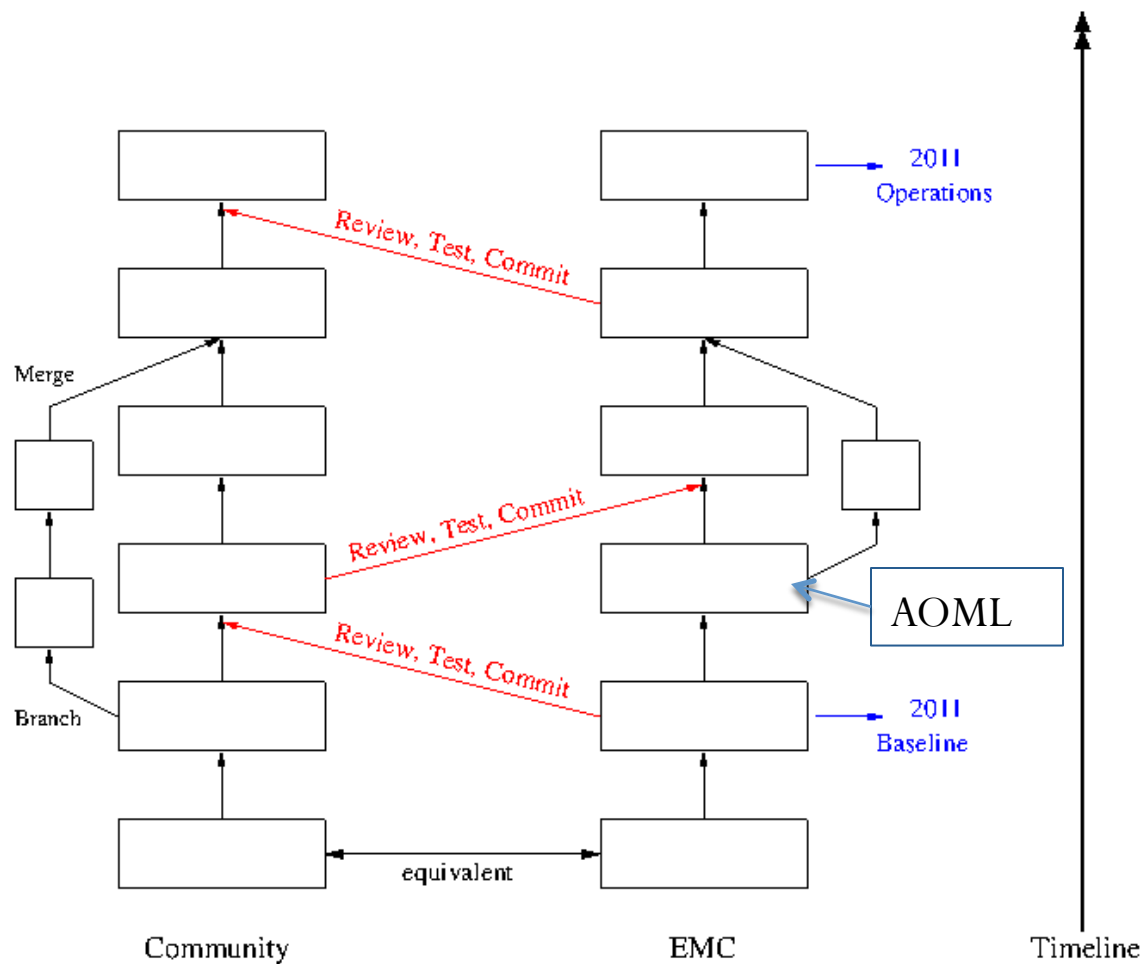
BACKGROUND

HWRF Code Management: Atmospheric Model



Challenges in Code Management

NCEP does not have rigorous software development practices



Complicated for codes that evolve quickly, like WRF (!)

For each update, need to review and test twice (!)

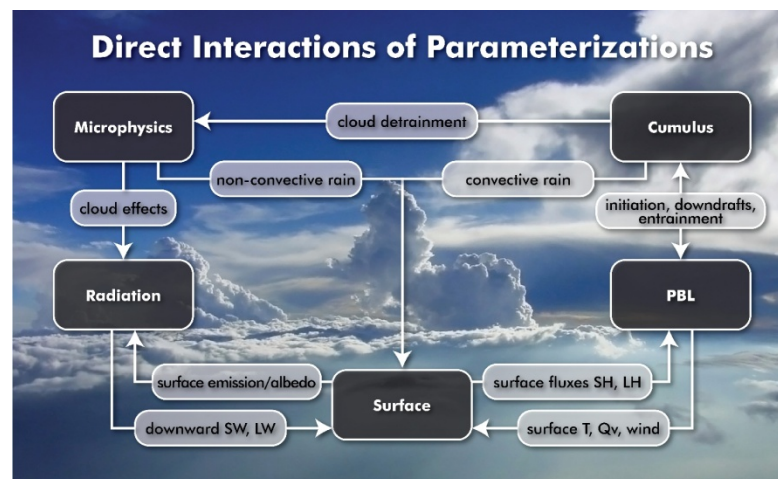
Prone to human error (!)

SVN log messages are lost in the process (!)

Continuous use of internal EMC repository for development adds overhead
We are working with EMC to make this more efficient

NWP Workshop on Model Physics

- Held at NCEP 26-28 July 2011 with 34 invited participants
- Recommended Action Items
 - EMC should establish a science advisory board to provide guidance on scientific priorities
 - EMC and DTC should work closely to promote R&O collaborations through working group meetings and workshops
 - NOAA/NWS should fund a substantial grants program for NWP weather research
 - DTC should establish a model evaluation testbed with a variety of datasets
 - NWP physics developers should make use of direct physical validation, special observation networks and simplified modeling frameworks
 - NOAA/NWS should acquire increased computing resources for developing the next generation high-resolution modeling systems



Summary of the “NWP Workshop on Model Physics with an Emphasis on Short-Range Weather Prediction”

A workshop organized by the DTC and NCEP/EMC was held at the World Weather Building in Camp Springs, Maryland on 26-28 July 2011. The goals of the two and a half day meeting were to find short-term opportunities for improving numerical weather prediction (NWP) models, and to establish a longer-term framework for closer collaboration between research and operations (R&O). ... The final portion of the meeting focused on identifying a path forward for promoting greater coordination of physics development between the R&O modeling communities.

http://www.dtcenter.org/events/workshops11/mm_phys_11

SYSTEMATIC ERRORS

- As implemented at DTC (using archived NCEP SREF ensemble output), downscaling decreased mean error (removed bias)
- Not always statistically significant

DTC Tests of SREF BiasCorrection and NAEFS Downscaling
2m Temp Mean Error – Aggregation for 10 Jun – 10 Jul 2011

